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Disastrous Forecasting of Fire Accidents in Assembly Occupancies

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Abstract

With rapid development of economy, fire accidents in assembly occupancies usually take place with enormous economy losses and personnel's casualty, it is necessary to how to forecast the occurrence of fire accidents according to fire statistic. The disastrous forecast model is established and fire accidents happened in one province are analyzed, it is found out that forecast precision of the model is better and the result is consistent with the actual value, it will provide a certain theory support for fire prevention.

Keywords: assembly occupancies; disastrous forecasting; fire accidents; forecasting model

1. Introduction

In recent years, the assembly occupancies increase in growing numbers with rapidly development of urban modernization. The fire happened in assembly occupancies takes a large proportion in total amount of fires in China. Fire numbers in assembly occupancies are 9192 in 2006, 20150 in 2007 and 16159 in 2008 respectively. Moreover, it will easily bring about catastrophic fire accidents, which lead to disastrous economic loss, enormous personnel's casualty and bad social influence. Accordingly it is extremely important for lowering economic loss and personnel's casualty to master fire occurrence regularity and make fire prevention countermeasures as soon as possible. Therefore, it is of great significance to predict fire occurrences of assembly occupancies.

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2. The Feasibility of Disastrous Forecasting Model

Disastrous forecasting model is a typical model in the grey system theory which was pioneered by Prof. Deng in 1982. The principle of grey prediction is to find regularities from discrete data [1], and its essence is to create new data series and establish new prediction model by dealing with raw data series and weakening its randomness. There are many complicated influencing factors for fire accidents. Although one fire accident has randomness and contingency other than regularity, many fire accidents during one period have certain probability regularity, which fluctuate within a certain range, some factors are certain but others uncertain in a fire, that is partially known and partially unknown [2], so disastrous forecasting model can be successfully applied in actual fire predication.

3. Establishment of Disastrous Forecasting Model

Basically, grey disastrous forecast is the prediction of abnormal value, a lot of disastrous dates will be predicted by studying disastrous date sequences and tracing their regularity,

3.1 The Steps of Disastrous Forecasting Model

Step 1: Original data sequence

The original data of fire accidents in assembly occupancies are:

$$x^{(0)}(t)=\left\{x^{(0)}(1),x^{(0)}(2),x^{(0)}(3),\cdots x^{(0)}(n)\right\}$$

A hold value ξ is established according to actual fire accidents in the province, and the values in $x^{(0)}(t)$ which are greater than ξ are picked out in order to make a new sequence, which is called disastrous sequence. The time abnormal value happened is called disastrous point, all disastrous point are denoted by q, all abnormal value are denoted by k, the mapping from abnormal value to disastrous point is obtained[3-4], its expression is $P:\{k\}\rightarrow\{q\}$ or denoted by $P(k)=q$, then

$$P^{(0)}(k)=\left\{P^{(0)}(1),P^{(0)}(2),P^{(0)}(3),\cdots P^{(0)}(n)\right\}$$

Step 2: Accumulated generating operation(AGO) for original data sequence

Based on the sequence $P^{(0)}$, the generating sequence can be done by AGO as follows:

$$P^{(1)}(k)=\sum_{i=1}^{k}P^{(0)}(i) \quad (k=1,2,3\cdots n)$$

Where $P^{(1)}(k)$ is the accumulated generating data, so the new sequence is :

$$P^{(1)}(k)=\left\{P^{(1)}(1),P^{(1)}(2),P^{(1)}(3),\cdots P^{(1)}(n)\right\}$$

Step 3: Mean sequence and differential equation

The mean sequence is

$$z^{(1)}=(z^{(1)}(2),z^{(1)}(3),z^{(1)}(4),\cdots z^{(1)}(n))$$

$z^{(1)}(k)$ is defined as:

$$z^{(1)}(k)=0.5P^{(1)}(k)+0.5P^{(1)}(k-1) \quad (k=2,3,4,\cdots n)$$

The grey differential equation is obtained as: $p^{(0)}(k)+az^{(1)}(k)=b$

Then the albefaction differential equation is: $\frac{dP^{(1)}}{dt}+aP^{(1)}(k)=b$

Where *a* is the developing coefficient and *b* is the grey input value.
Where:

$$u=(a,b)^{\mathrm{T}}$$

$$Y_n=\left(P^{(0)}(2),P^{(0)}(3),P^{(0)}(4),\cdots P^{(0)}(n)\right)^{\mathrm{T}}$$

$$B=\begin{pmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \mathrm{M} & \mathrm{M} \\ -z^{(1)}(n) & 1 \end{pmatrix}$$

Step 4: Least square estimation of parameters
The forecasting value is obtained by least square estimation as:

$$\hat{u}=(\hat{a},\hat{b})^{\mathrm{T}}=(B^{\mathrm{T}}B)^{-1}B^{\mathrm{T}}Y_n$$

Posting a and b into differential equation, then, get the solution:

$$\hat{P}^{(1)}(k+1)=\left(P^{(0)}(1)-\frac{b}{a}\right)e^{-ak}+\frac{b}{a}$$

Forecasting equation is:

$$\hat{P}^{(0)}(k+1)=(1-e^{a})\left(P^{(0)}(1)-\frac{b}{a}\right)e^{-ak}$$

3.2 Model Precision

In order to make sure whether the model could be used to predict, prediction accuracy should be verified. Whether a model is qualified or not can only be known by various kinds of experiments, only those passed the examination can be used for forecasting[5], residual method and accuracy test method are often adopted.

Where

$e^{(0)}(k)$ is relative residual, $e^{(0)}(avg)$ is mean residual, p^{0} is prediction accuracy.

$$e^{(0)}(k)=\frac{p^{(0)}(k)-\hat{p}^{(0)}(k)}{p^{(0)}(k)}\times 100\%$$

$$e^{(0)}(avg)=\frac{1}{n}\sum_{k=1}^{n}\left|e^{(0)}(k)\right|$$

$$p^{0}=(100-e^{(0)}(avg))\%$$

4. Application Example

Fires happened in one province in the first half year are listed in table 1.

Table 1 Fire numbers

Month	1	2	3	4	5	6
Fire numbers	25	28	32	31	33	34

The original data of fire accidents in assembly occupancies are obtained as:

$$x^{(0)}(t)=\left\{x^{(0)}(1),x^{(0)}(2),x^{(0)}(3),x^{(0)}(4),x^{(0)}(5),x^{(0)}(6)\right\}$$
$$=\left\{25,28,32,31,33,34\right\}$$

Hold value ξ=25 is selected combined with actual situation and fire level of the province; i.e., if fire numbers are more than 25, fire accidents are thought to be in the multiple period and needed to control and regulate, according to abnormal value, then:

$$x_{\xi}^{(0)}(t)=\left\{x_{\xi}^{(0)}(1),x_{\xi}^{(0)}(2),x_{\xi}^{(0)}(3),x_{\xi}^{(0)}(4),x_{\xi}^{(0)}(5)\right\}$$
$$=\left\{28,32,31,33,34\right\}$$

The mapping from abnormal value k to disastrous point q is obtained:

$$P^{(0)}(k)=\left\{P^{(0)}(1),P^{(0)}(2),P^{(0)}(3),P^{(0)}(4),P^{(0)}(5)\right\}$$
$$=\left\{2,3,4,5,6\right\}$$

Accumulated generating operation (1-AGO) for $P^{(0)}(k)$:

$$P^{(1)}(k)=\left\{P^{(1)}(1),P^{(1)}(2),P^{(1)}(3),P^{(1)}(4),P^{(1)}(5)\right\}$$
$$=\left\{2,5,9,14,20\right\}$$

Constituting data matrix B and vector Y_n is as follows:

$$B=\begin{bmatrix}-3.5 & 1\\ -7 & 1\\ -11.5 & 1\\ -17 & 1\end{bmatrix}\qquad Y_n=\begin{bmatrix}3\\4\\5\\6\end{bmatrix}$$

Parameter vector $\hat{u}$ is calculated with matlab program:

$$\hat{u}=(\hat{a},\hat{b})^{\mathrm{T}}=(B^{\mathrm{T}}B)^{-1}B^{\mathrm{T}}Y_n=\begin{bmatrix}-0.22\\2.3545\end{bmatrix}$$

Forecasting equation is:

$$\hat{P}^{(0)}(k+1)=(1-e^{a})\left(P^{(0)}(1)-\frac{b}{a}\right)e^{-ak}=2.5085e^{0.22k}$$

Prediction accuracy of the model is 97.3625%(see table2), the precision is very high, so the model is correct and applicable to predict, the prediction result is obtained as:

$$\hat{P}^{(0)}(7)=7.5360$$
$$\hat{P}^{(0)}(8)=9.3904,$$
$$\hat{P}^{(0)}(7)-\hat{P}^{(0)}(6)=7.5360-6.0477\approx 1.5$$
$$\hat{P}^{(0)}(8)-\hat{P}^{(0)}(6)=9.3904-6.0477\approx 3$$

So, multiple period of fire accidents are from the middle of July to the middle of August and September in assembly occupancies. This requires fire department to take effective measurements during these periods of time, only the assembly occupancies are supervised and investigated in order to prevent the hidden danger of fire accidents so that the occurrence of fire accidents can be reduced and the loss of casualties and possessions can be avoided.

Table 2 Residual sequence

Original sequence $P^{(0)}(k)$	2	3	4	5	6
Simulation sequence $\hat{P}^{(0)}(k)$	-	3.1258	3.8950	4.8534	6.0477
Relative residual sequence $e^{(0)}(k)$	-	-4.19%	2.63%	2.93%	-0.8%
Mean residual sequence $e^{(0)}(avg)$	2.6375%				
Prediction accuracy p^0	97.3625%				

5. Conclusions

The model is constructed by using the methods of grey disastrous forecasting in this paper. It fully takes advantage of the original data (usually more than four) to predict the fire numbers in assembly occupancies. The grey disastrous forecasting model which is established works effectively so that the conclusion can be drawn as follows:

(1)The method of establishing the model is right, effective, and accurate, which is appropriate for predicting the fire accidents in assembly occupancies. Besides, it is feasible for short-time predication. As for the long-time prediction, we can reestablish a model and do rolling forecast by making the predicted value as new data.

(2)The latest data should be used as much as possible while establishing a model so that the model is more accurate and practical.

(3)The model of grey disastrous forecasting can effectively forecast the fire accidents in assembly occupancies. Therefore, the fire department can make a decision ahead of time according to the predicted result. They can also investigate the hidden danger of fire accident in assembly occupancies and prevent lots of casualties and economic loss.

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